BACKGROUND ILLUMINATION AS A FACTOR IN THE ATTACHMENT OF BARNACLE CYPRIDS

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Introduction

Various authors, following Visscher (1927), have shown that certain species of barnacles attach in greater numbers to darker surfaces. McDougall (1943), by means of an experiment designed to test the effect of varying degrees of illumination, demonstrated that larvae of *Balanus eburneus* have a tendency to settle most abundantly upon collectors placed in less brightly illuminated areas. Pomerat and Reiner (1942) showed that *Balanus eburneus* larvae attach more readily to black rather than to opal panels when they are exposed in the sea for several days. These investigators also observed that when light is at a minimum, during the hours of darkness, the differences do not occur but that attachments are remarkably similar on light and dark panels. This suggested that attachment to darker panels during daylight is a phototropic response to the contrasting effect of dark surfaces against lighter general surroundings. The purpose of the present study was to investigate whether in fact, contrasting surroundings are effective in promoting attachment. A further objective was the determination of the maximum distance at which the degree of illumination of a background surface is effective in influencing attachment to transparent surfaces.

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Effect of Contrasting Backgrounds

In the experiments designed to determine whether contrasting surroundings influence cyprid attachment, provision was made for base plates of black, transparent, and opal Carrara glass plates 10″ × 12″ in size. Upon each of these were mounted 4″ × 10″ black and opal Carrara glass collecting panels, in such a way as to be surrounded by a 2 inch border of the base panel.

The plates were supported by a wooden frame. The glass bases were arranged one inch apart and the paired black and opal collectors were separated by two inches. Thus, a series of contrasts was offered between the pairs of black and opal plates and the three surrounding borders of black, opal, and transparent glass. The barnacles were counted following attachment upon the collectors, each of which offered an exposed area of 36 sq.in. In the locality where the investigations

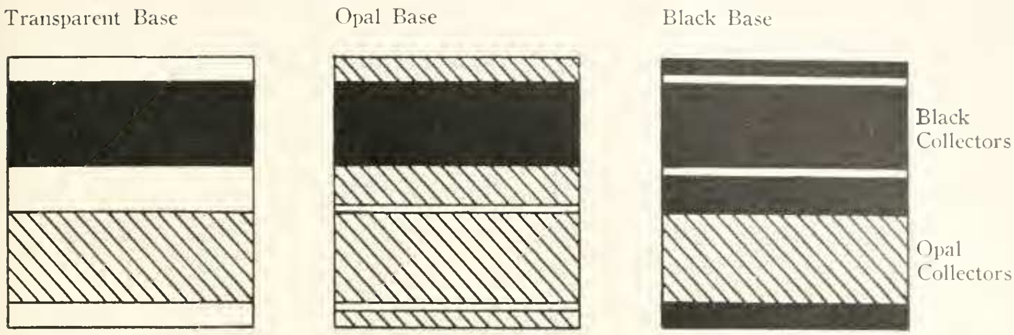

FIGURE 1. Arrangement of black and opal collectors upon black, opal, and transparent bases.

were carried out the adults of *Balanus eburneus* were the barnacles most commonly found, and all attachments were assumed to belong to this species.

The apparatus for the first series of experiments was lowered into the sea with the plates in a vertical position at a mean depth of three feet from the surface. Six successive experiments were conducted with an average duration of 36 hours. At the end of each period the paired plates were removed and washed gently with fresh water to remove salt crystals and silt. Counts were then made of the cyprids and of the metamorphosed barnacles, with the results shown in Table I.

Further experiments were conducted with the plates exposed horizontally, in order to collect attachments on the lower surface. The mean depth of the plates below the surface of the sea was seven feet. Five experiments were conducted,

TABLE I

Barnacles attaching to vertical collectors with borders of varying contrast

Experiment	Date of exposure	Black collector			Opal collector		
		Borders			Borders		
		Transparent	Opal	Black	Transparent	Opal	Black
I	7- 2-44	68	67	35	15	17	8
II	7- 4-44	300	293	458	249	183	233
III	7- 6-44	73	115	59	8	5	7
IV	7- 8-44	120	175	121	15	38	35
V	7-10-44	89	97	86	17	7	25
VI	7-12-44	137	152	162	23	23	18
Total		787	899	921	327	273	326
Average		131	150	154	55	46	54

Table II

Barnacles attaching to horizontal collectors with borders of varying contrast

Experiment	Date of exposure	Black collector			Opal collector		
		Borders			Borders		
		Transparent	Opal	Black	Transparent	Opal	Black
VII	7–17–44	653	503	703	80	114	171
VIII	7–20–44	757	692	711	94	142	194
IX	7–23–44	582	720	686	142	249	340
X	7–26–44	620	855	701	254	328	437
XI	7–31–44	526	582	564	194	230	303
Total		3138	3352	3365	764	1063	1445
Average		628	670	673	153	213	289

with exposure periods varying from 72 to 120 hours. The results are shown in Table II.

Upon horizontal and vertical black collectors and regardless of the nature of the surroundings, greater attachments occurred upon the black collectors as compared with the opal. The total number of organisms on all black horizontal collectors amounted to 9855 compared with a total of 3272 for opal horizontal collectors, giving a black/opal distribution ratio of 3.0. The total populations on black and opal vertical collectors were 2607 and 926 respectively, giving a ratio of 2.8. These ratios, though greater, qualitatively substantiate the findings of Pomerat and Reiner (1942) whose ratio for attachment numbers upon black and opal collectors was 1.8 (Table III).

Table III

Total number of barnacles on black and opal collectors

	Black collectors	Opal collectors	Ratio $\frac{\text{Black collectors}}{\text{Opal collectors}}$
Horizontal	9855	3272	3.0
Vertical	2607	926	2.8

Attachments to black vertical collectors did not vary greatly with the type of surrounding, but were least in the case of the transparent border (Table I). With black collectors, borders of black, transparent and opal, in this order, afford increasing contrasts. Had the contrast been effective, greater attachments should have occurred upon collectors with the opal and transparent borders rather than with the black border. Attachments upon black horizontal collectors also failed to show significant differences when the three different surroundings were employed, although they were least in the case of a transparent border (Table II).

The frequencies of attachment upon vertical opal collectors did not show any correlation with increasing degree of contrast but were similar in all instances (Table I). The horizontal opal collectors gave somewhat different results (Table II). In this series of experiments the greatest attachments were found on the collectors with the black borders. The least numbers, however, were observed on collectors with transparent borders and intermediate attachment frequency occurred with opal borders. In these experiments the least degree of contrast was offered by opal surroundings of similar material to the collectors and the greatest degree by black surroundings which afforded the minimum possibilities of transmitted and reflected light. There was not, therefore, a consistent correlation between the intensity of attachment and the degree of contrast between collector and surroundings.

In an attempt to explain the results, the question of variation in the general intensity of illumination beneath the panels may be considered. The amount of transmitted and reflected light was greatest around horizontal opal collectors with transparent surroundings. The reflected light which alone fell below opal collectors with the opal borders was less intense than the light in the former case and it was under this condition that frequency of attachment was found to be increased. The opal collectors with black borders, which reflected the least light of the three types of surrounding were found to have the greatest attachment. Thus, with the decrease in general illumination beneath opal collectors, there was an increase in attachments, and it appears that attachment frequencies are here related to the degree of shading under the collectors caused by the varying opacity and reflection of the surroundings.

The horizontal black collectors were found to have distinctly greater attachments when combined with a black border. They also showed least attachments with a clear border. The black collectors, therefore showed a correlation, not with contrast but rather with the degree of shading which is at a maximum where both collector and surroundings are black.

In the case of both black and opal vertical collectors, the shading effect of the border is less pronounced, due to the fact that much of the light enters the water at a more or less vertical angle. The hypothesis that general shading stimulates attachment would fit in with the observed facts about attachments to these series. The difference between the amount of light reflected by black or opal collectors is more significant than that reflected by the relatively small borders, and hence accounts for the relatively small differences among attachments to black collectors with different surroundings or among attachments to opal collectors with varied surroundings. The differences between attachments to the two types of collector with each surrounding are relatively greater.

Distance At Which Background Illumination Is Effective

The equipment designed for the question of determining the maximum distance at which black or opal surfaces are effective in stimulating a cyprid to attach consisted of a wooden frame 30″ long, 32″ wide, and 12″ high. This frame supported vertically two transparent glass plates. Behind the first glass plate was mounted a black plastic panel in such a manner that it might be moved to varying distances. The second transparent glass plate without any backing was used as the control. A second series of transparent glass plates at the opposite side of the frame were treated in the same manner with the exception that an opal plastic panel was used instead of a black one. The movable black plastic panel and the movable opal plastic panel were set at increasing distances from the clear panel for successive experiments. Each transparent glass plate from which the barnacles were counted, offered 54 sq.in. of surface area. They were exposed at a mean depth of three feet from the surface for an average duration of 72 hours. In the successive experiments the black and opal plastic movable panels were placed at 2″, 3″, 4″, and 6″ behind the transparent collectors.

The results (Table IV) show a general decline in the attachments to the glass collector as the black movable plate was moved away. The maximum distance at

TABLE IV

Attachment of barnacles to transparent panels with movable backgrounds

Distance of background from collector	Movable black	Control transparent	Ratio Movable/Control	Movable opal	Control transparent	Ratio Movable/Control
2 inches	2998	778	3.9	1258	511	2.5
3 inches	803	355	2.3	835	336	2.5
4 inches	3759	1707	2.2	3686	2806	1.3
6 inches	458	453	1.0	906	780	1.2

which it influenced attachment, as determined by comparison with the control, was between four and six inches. The same general decline in population was noted for the opal plates although the maximum influencing range was greater than six inches. Since attachment is influenced by the movable panels at a distance, it is obvious that the light reflection at the actual collecting surface is not the principal stimulating factor. The facts are more readily explained by assuming that the intensity of general illumination in the vicinity of the collector is the important factor and that where this is reduced by the proximity of black backplates greater attachment occurs. Decreasing distances of the opal backplate, while giving a superficial appearance of increased light intensity, probably succeed in blocking the light passing through the collecting panel. Thus increased attachment under these conditions may still be due to decreased general illumination.

These general conclusions agree with the results of the contrasting background experiments described in the first part of the paper where a relationship appeared to exist between the number of attachments and the amount of shading caused by the type of background employed. The decreased intensity of illumination in the general vicinity of the collector, as opposed to the conditions of illumination immediately upon the collector itself may increase attachment by causing a response in the cyprid. This response is in the nature of a conditioning towards subsequent attachment, or the development of a physiological state favoring a subsequent attachment response to a contact stimulus. The possibility of a tropism is not supported by the contrast experiments.

In the light of the above conclusions it may be interesting to recall the experiments of Schallek (1943) and Whitney (1941) who maintain that directional light is not to any great degree present under natural aquatic conditions but that conditions of diffuse light almost invariably predominate. This diffuse light is a naturally occurring phenomenon, whereas light from any one direction may not predominate sufficiently for a tropism to occur.

Summary

1. Experiments were conducted to determine the effect of contrasting surroundings upon the frequency of attachment of *Balanus eburneus* larvae to opaque black and opal glass collecting surfaces. Further experiments were carried out to determine to what extent the number of attachments of transparent collectors was influenced by black and opal backgrounds placed at varying distances.

2. Greater numbers of attachments occurred upon the under side of horizontal rather than vertical, and upon black rather than opal collectors, thus confirming the observations of previous authors.

3. No correlation was found between the degree of contrast shown in the collector and surroundings, and the frequency of attachments.

4. Both black and opal surfaces were found to increase frequency of attachment when placed behind transparent collectors up to distances of six inches.

5. A definite dependence was found to exist between the frequency of attachment and a decrease in the intensity of general illumination in the area immediately beneath horizontal opal collectors. Similarly, the influence of movable backgrounds appeared to be in the nature of a shadow effect. It is suggested that "shading" acts as a stimulus which brings about favorable physiological conditions for the subsequent attachment of barnacle larvae and that the amount of light reflected from the collecting surface is only important insofar as it affects the general "shading" in the vicinity.

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